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ScienceDirect
Procedia Computer Science 91 (2016) 334 – 340
Procedia Computer Science

Information Technology and Quantitative Management (ITQM 2016)

A New Feed-in-Tariff Pricing Approach of Distributed Photovoltaic Generation in China

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Abstract

Recently, distributed photovoltaic generation has developed rapidly, however the pricing mechanisms are still not mature enough. In China, benchmark price policy based on resource regions is carried out, and distributed photovoltaic generation is uniform subsidized according to the whole power at present. In this paper, taking the technical features and cost characteristics of distributed photovoltaic generation into account, a new feed-in-tariff pricing approach is proposed on the basis of "cost plus profit", and adopted to distinguish different resource regions and user types. Pricing model is given and simulated for residential and commercial user respectively. At last, sensitivity analysis of some important factors is carried out. The study can provide a good reference for the formulation of reasonable pricing mechanism, and contribute to the development of distributed photovoltaic power.

Peer-review under responsibility of the Organizing Committee of ITQM 2016

Keywords: distributed photovoltaic generation, Feed-in Tariff, cost plus profit

1. Introduction

As the economy of China develops rapidly, dependence and demands on energy keep increasing. As an important resource, oil has drawn widely attention. There are abundant related researches, such as optimization of oil-importing combination [1-2], oil price volatility and impact of oil price volatility to country risk [3]. However, high dependence on oil importing may influence energy security to some extent. Against that backdrop, promotion and application of distributed photovoltaic generation will definitely decrease high dependence on coal-fired for the current energy consumption structure and further reduce emissions in China.

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Peer-review under responsibility of the Organizing Committee of ITQM 2016
doi:10.1016/j.procs.2016.07.089

Solar energy resources in China are rich and fit to generation, which is a significant advantage in solar energy application. Meanwhile, it is safe, noiseless, low pollution [4]. By the end of 2015, cumulative installed capacity of distributed photovoltaic generation in China has been up to 6060 megawatt, and mainly distributes in east region where power load is more concentrated than other regions. It is further expected that by 2020, 43500 megawatt of distributed photovoltaic generation will be built. Despite a booming prospect, in China the pricing mechanisms of distributed photovoltaic generation is still in its infancy and not mature enough, which is against the development of photovoltaic generation. At present, according to the policy [2013] No.1638 issued by the National Development and Reform Commission (NDRC), feed-in tariff of photovoltaic generation is 0.42 RMB/KWH. Investment policy is one of the important factors which affects the generation capacity investment [5]. How to price for photovoltaic generation reasonably and flexibly on the premise of considering as more factors as possible is the focus of this paper.

Feed-in tariff of photovoltaic generation means the settlement price from the generation system to power grid, in other words, the purchase price to the generation system. Researches about the price of photovoltaic generation emphasize on fixed purchase price mechanisms which have been widely applied in dozens of countries. Menanteau et al [6] proposed a bid mode. Through a bid, lower price will won the purchase price and this mode can effectively promote companies to decreasing the cost of PV generation. Lesser and Su [7] stressed that FIT (Feed-in-Tariff) policy-making should pay more attention to subsidies, subsidy methods (fixed or progressive decreasing) and subsidy term. Coute and Gagnon [8] pointed that fixed purchase price can provide a fixed subsidy for the renewable energy in a specific period. That can decrease the uncertainty of investment and contribute to the development of photovoltaic industry. Rigter and Vidican [9] suggested determining the purchase price by net present value (NPV) method. In their paper, purchase price of small photovoltaic system is determined in China by discounting all the cost in every period, including investment in the fixed assets, loan, generation income, operation costs et al, to be the current values. What's more, Fouquet and Johansson [10]，Langniß et al [11]suggested that although the fixed purchase price is constant per KWH, it can also change with technological types, installation size and resource endowment. In whatever way the purchase price is decided, subsidy level of FIT is closely related with the cost of photovoltaic generation [12].

Domestic researches about purchase pricing mechanisms are at the preliminary stage. Purchase pricing mechanism gradually transit from the initial approved electricity and franchise bidding project to fixed purchase pricing. After studying policies in other leading producers of solar power in the world, Luo and Lin [13] suggested that China should form stable and transparent pricing mechanisms based on better geographic advantage than European countries and promote core technology research by fiscal and special funds. Photovoltaic pricing is gradually decreasing due to the cost reduction led by learn effect. Hu [14] introduced two batches of photovoltaic power station franchise bidding projects organized by National Energy Administration. The lower pricing is employed as purchase price. He suggested that this pricing mechanism is fit for markets with high variabilities and contributes to explore reasonable cost of photovoltaic generation. However, on the other hand, this mechanism can also lead to low-price competition, and the final bidding price may departure from the actual cost. National Development and Reform Commission makes some analysis on photovoltaic pricing mechanisms selection in order to adapt market development. Firstly, reasonable standards of the electricity price and subsidies are determined and carry out the demonstration project bidding by the end of 2020. Cost of photovoltaic generation is expected to the current level of wind power and biomass power. Combined with the electricity power reform, pilot projects of photovoltaic generation bidding will be launched in some regions by the end of 2030. After that, photovoltaic generation achieves scale development and is directly involved in market competition.

At present, the subsidy policy for photovoltaic generation is the same nationwide and does not have any difference. No matter where the project is and what scale the project is, the subsidy is the same. Further, in China decreasing and exit mechanism for subsidy has not constructed. If the subsidy remains unchanged, high profits will be acquired with technological progress, and further may lead to excess capacity. In order to make some attempts to photovoltaic generation pricing, combined with the characteristics of technology and cost for domestic photovoltaic generation industry, a new pricing mechanism is proposed on the basis of "cost plus profit" by distinguishing different resource regions and user types in this paper.

The remainder of this paper is organized as follows. In Section 2, impact factors and pricing models for distributed photovoltaic generation are introduced. Then in Section 3, for different users, simulations are carries out based on the pricing model proposed in Section2. Further sensitivity analysis of key impact factors are also implemented in Section3. Finally, conclusions are made in Section 4.

2. Model and specification

In this section, a new feed-in-tariff pricing approach is proposed on the basis of "cost plus profit". Impact factors and models of pricing will be introduced respectively. With respect to pricing of distributed photovoltaic generation, the following three principles should be abided by. Firstly, pricing should contribute to the development of distributed energy. Final determined price should provide certain profits for both investors and grid corporations under the premise of compensating the reasonable investment costs. Secondly, pricing should reflect real market value. With improvements in distributed energy generation technology, the costs will gradually decrease. In this situation, price should be dynamically adjusted with costs in order to reflect the real market value. At last, pricing should contribute to coordinated development of distributed energy in different regions. Resource endowment and generation costs are very different for different regions, as a result, a reasonable pricing mechanism should reflect the regional difference.

2.1 Impact factors of pricing

Total cost of photovoltaic generation project generally includes the project investment cost, operation and maintenance cost, financial cost.

Project investment cost is the main part of the total costs, including the costs for equipment procurement, construction and installation, and sites. The second class of cost is operation and maintenance costs, generally includes materials expenses, repair costs, wages and welfares, amortization charges and so on. Wages and welfares of staffs vary with different regions. Another potential cost is financial costs, which refers to the costs generating from the financing process. It is general determined by the structure of costs, and further influenced by markets factors to a great extent.

Equipment procurement, more than 60% of which is battery package cost, is the most important part for the initial investment. A good news is that equipment procurement cost follows the learning curve. To be specific, unit cost will be decrease along with improvements of technical level. Given this, unit capacity cost is defined as dynamic investment of unit generator installed power (RMB/kW). On one hand, in recent years, cost of photovoltaic system in China has experienced a significant reduction. During 2007-2012, annual decline is more than 30%. In 2014 the reduction is 10%, and the domestic price of photovoltaic system reaches to 8-9.5 RMB/W. However, on the other hand, construction costs of operation and maintenance costs, loan interests of financial costs and other costs keep increasing in recent years, the annual growth is up to 6%、8% and 7% respectively. In despite of the increasing fact of these costs, the growth exerts little influence on unit capacity cost in practice because these costs account for very small part of the total costs.

Finally, resource endowment and the climate condition in a region can also impact the costs. For different resource regions, annual utilization hours are different. In this paper, three regions are distinguished and characteristics are listed in Table 1.

Table 1. Characteristics for different resource regions

Region	Latitude	Annual total radiation for horizontal plane	Enhance of radiation for inclined plane	The range of annual utilization hours	Selected annual utilization hours
	degree	kWh/ Sqm	%	h	h
I	35-50	1750-2300	15-25	1600-2200	1800
II	20-55	1400-1750	10-25	1400-1600	1500
III	3-40	1050-1400	0-20	1000-1400	1200

2.2 Pricing Models

In this paper, a new pricing mechanism, considering both cost and profit, is proposed. Specific pricing model is defined as follows:

Feed-in Tariff = Allowable Cost + Reasonable Return + Tax (1)

- Allowable Cost

Allowable Cost= Depreciation Cost+ Operation and Maintenance Cost+ Financial Cost (2)

Firstly, Depreciation Cost is evaluated by Fixed Assets Value verified by the regulatory authorities and integrated allowance for depreciation in centralized photovoltaic generation project. With straight-line depreciation method, Depreciation Cost is evaluated as follows.

Depreciation Expense = Fixed Assets Value * (1-Residual Rate) * Depreciation Rate (3)

In this paper, Fixed Assets Value= Unit Capacity Cost * Installed Capacity (4)

Secondly, Operation and Maintenance Cost includes materials expenses, repair costs, wages and welfares, amortization charges and so on. It can be evaluated with single or composite estimation.

Single estimation is operated as follows.

Materials Expenses= Fixed Assets Value * Depreciation Rate (5)

Repair Costs= Fixed Assets Value * Repair Rate (6)

Wages and Welfares= Population * Average Wage * (1+ Social Insurance Rate) (7)

For composite estimation, difference in cost drivers is not considered, and a uniform rate is employed.

Operation and Maintenance Cost= Fixed Assets Value * Operation and Maintenance Rate (8)

Finally, the financial cost is generally evaluated by two methods, namely ‘equal repayment of principal’ and ‘equal repayment of principal and interest’.

- Reasonable Return

Reasonable return refers the reasonable benefits of the enterprises. According to current policy in China, pre-tax benchmark yield for power projects is 8%.

- Tax

Tax is composed by value-added tax (VAT), additional VAT rates and income tax. In China, there are some preferential policies on taxes for distributed photovoltaic generation project. According to the current policy, VAT can be returned 50% once collected. Additional VAT rates is carried out as 8%. Among that, urban maintenance and construction tax is 5% while educational surcharge tax is 3%. Income tax rate is 25%, and "avoid 3 subtract 3" preferential policies are implemented.

3. Simulations

3.1 Residential user

- Parameters setting

In this part, distributed photovoltaic generation projects for the residential users in Region II is selected as an example. Before pricing, some parameters need to be stated. Installed capacity is 5 kWp, and unit capacity cost is 9 RMB/W. As a result, the initial investment is 45 thousand. In Region Ⅱ, the effective time is 1500 hours. The system efficiency is 75%, and average annual production capacity is 5000 kWh. In this paper, Operation and Maintenance Cost is not be considered temporarily. It is assumed that the operation period is 25 years, and the return rate on capital is 8%. Considering the fact that the capital is small, they are all regarded as own funds. In other words, there is no financial cost.

- Price evaluation

Based on the pricing mechanism combining cost and profit, Feed-in Tariff for residential user (including tax) is estimated as 1.17 RMB/kWh. Extracting the subsidy of 0.42 RMB/KWh, the difference is 0.75 RMB/kWh. This price is higher than the local coal-fired units feed-in tariff benchmarking, and also higher than sales price to residents. As a result, from the perspective of "economics", under the current subsidy policy, the economy of distributed photovoltaic generation projects is poor for residential users.

- Sensitivity analysis

There are many factors which can influence the Feed-in Tariff for distributed photovoltaic generation project. In this part, sensitivity analysis are implemented for three factors, namely unit capacity price, the effective hours determined by the resource endowment and annual operation and maintenance rate. By adjusting the three factors, two scenarios are given respectively. For unit capacity price, scenario 1 is increasing 20% while scenario 2 is decreasing 20%. For the effective hours, Region I and Region III are compared with Region Ⅱ. For the third factor, 1% and 2% annual operation and maintenance rate are regarded as scenario 1 and 2 respectively. The sensitivity analysis results are shown in Table 2.

Table 2. Sensitivity analysis for three factors （residential user）

	Factors	Unit	Scenario 1	Benchmark	Scenario 2
1	Unit capacity price	RMB/W	7.5	9	10.8
	Feed-in Tariff	RMB /kWh	1.40	1.17	0.97
2	Annual effective hours	h	1200	1500	1800
	Feed-in Tariff	RMB /kWh	1.46	1.17	0.97
3	Annual operation and maintenance rate	%	1	0	2
	Feed-in Tariff	RMB /kWh	1.28	1.17	1.39

The simulation results suggest that the selected factors can exert influence on Feed-in-Tariff Price for distributed photovoltaic generation projects, and unit capacity price and annual effective hours show more significant influence.

3.2 Commercial user

- Parameters setting

In this part, distributed photovoltaic generation projects for the commercial users in Region II is selected as an example. Installed capacity is 300 KWp, and unit capacity cost is 8.5 RMB/W. As a result, the initial investment is 2.55 million. In Region Ⅱ, the effective time is 1500 hours. The system efficiency is 75%, and average annual production capacity is $3.16*10^5$ KWh. In this situation, operation and maintenance rate is set as 2%. It is assumed that the operation period is 25 years, and the return rate on capital is 8%. Considering the total capital, own loan occupies 20%. The length of commercial loan is 10 years, and the interest rate is 4.9%.

- Price evaluation

Based on the pricing mechanism combining cost and profit, Feed-in Tariff for commercial user (including tax) is estimated as 1.12 RMB/KWh. Extracting the subsidy of 0.42 RMB/KWh, the difference is 0.7

RMB/KWh. This price is higher than the benchmarking feed-in tariff of local coal-fired power generating units, but lower than that of the local residential sales. As a result, we can find that under the current subsidy policy, distributed photovoltaic generation projects is economical and feasible for the own use of commercial users.

- Sensitivity analysis

There are many factors which can influence the Feed-in Tariff for distributed photovoltaic generation project. In this part, sensitivity analysis is implemented for three factors, namely unit capacity price, annual utilization hours and annual operation and maintenance rate. By adjusting the three factors, two scenarios are given respectively. For unit capacity price, scenario 1 is increasing 20% while scenario 2 is decreasing 20%. For the effective hours, Region I and Region III are compared with Region Ⅱ. For the third factor, 1% and 3% annual operation and maintenance rate are regarded as scenario 1 and 2 respectively. The sensitivity analysis results are shown in Table 3.

Table 3. Sensitivity analysis for three factors （commercial user）

	Factors	Unit	Scenario 1	Benchmark	Scenario 2
1	Unit capacity price	RMB/W	7.08	8.5	10.2
	Feed-in Tariff	RMB /kWh	0.94	1.12	1.36
2	Annual effective hours	h	1200	1500	1800
	Feed-in Tariff	RMB /kWh	1.40	1.12	0.94
3	Annual operation and maintenance rate	%	1	2	3
	Feed-in Tariff	RMB /kWh	1.02	1.12	1.23

The simulation results suggest that the selected factors can exert important influence on Feed-in Tariff for distributed photovoltaic generation projects, and unit capacity price and annual utilization hours show greater influence.

4. Conclusions

A pricing mechanism based on “cost plus profit” is proposed and simulations are carried out for inhabitant and commercial users respectively. Simulation results suggest that considering the development stage in China, investment recovery period is long for distributed photovoltaic generation projects, especially for residential users. If the policy support for price is not strong enough, the investment motivation will be reduced, which will limit the further development.

From the perspective of pricing mechanisms, Feed-in Tariff for distributed photovoltaic generation projects is suggested to employ the fixed price, determining the price by considering both the cost and profit. Further, the pricing mechanism should distinguish different resource regions and user types, and finally achieve market pricing mechanism.

Acknowledgements

The Science and Technology Project, “Distributed energy pricing research on theory, model and the application”, in 2014 from State Grid Corporation of China is greatly acknowledged.

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